PEDESTRIAN STUDIES AND ANALYSIS OF PEDESTRIAN LEVEL OF SERVICE AT DURGA NAGAR INTERSECTION IN VIDISHA CITY

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Abstract: The study was aimed at improving the conditions of the road and designing roads for future providing better safety for pedestrians. Pedestrians form the largest single road user group and also are the most unsafe road users. The one cannot restrict the movement of Pedestrian through lanes or other specific routes; although, the physical boundaries around them such as the presence of walkways or pedestrian ways shall restrict them. The development of a pedestrian environment means more than laying down a footpath or installing a signal. Walking is cost-effective, environment friendly and possesses significant health benefits. To get these benefits from walking, the most important task is to ensure safest road for movement of the pedestrians. The main factors considered for the determination of Pedestrian LOS were through number of pedestrians, number of lanes, critical headway, probability delayed crossing, probability blocked lane, average delay to wait for adequate gap and pedestrian delay. Pedestrian delay is one of the key performance indicators for pedestrian level of service. During study it is observed that large number of pedestrians crossing National Highway -146 i.e. 12869 Pedestrian in a week. Further, it is determined that study area falls under Level of Service (LOS) – D.

Key word – **P-LOS, Delay, Crosswalk, Intersection**

1 INTRODUCTION

1.1 GENERAL:
According to the HCM:
"As volume and density of traffic increase, pedestrian speed decline. As pedestrian space decreases, the degree of mobility afforded to the individual pedestrian declines, as does the average speed of pedestrian stream"

People walk for many reasons as to go to a neighbor's house, for school, or to get to a business meeting. People also walk for refreshment and health benefits or for the enjoyment of being outside. Some pedestrians must walk to destinations if they wish to travel independently. This is a public responsibility to provide a safe, secure, and comfortable system for all people who walk. In this research will discuss about the pedestrian problems, characteristics, different level of services, and design principles of pedestrian facilities. There are many problems related to safety and security of pedestrians.

Walking is one of the most significant travel modes in urban & suburban areas. However, the concerns towards pedestrian comfort and safety are always skipped in transportation planning, designing, execution and management. The efforts are required to make more environment-friendly facilities for pedestrian for providing a safe walking environment.

The locations where Intersection exists are the most complicated locations on the road because the traffic movement in different directions wants to use the same space at the same time. The pedestrians also required some space to cross the road at the same time. Hence, there is a high prospect of conflict between pedestrian and vehicular traffic. In India, traffic nature is mostly assorted comprising different characteristics of vehicles. The vehicles of all categories use the same space or any unorthodox position of the highway based on the actual availability of the space at that moment without any control. Under these mixed traffic conditions; pedestrians are losing the movement space. The several pedestrian's facilities like sidewalks and medians provide the separation of pedestrian traffic from the other vehicular traffic. The implementation of these facilities enhances pedestrian safety and comfort. The solution provided by these pedestrian facilities shall be improved in a good manner for good transportation planning.

In India, urbanization began to accelerate exponentially which results in a major increment in urban population because interest towards life in cities & urban areas increasing. As per Census Survey-2011, the urban population is 31% i.e. 387 million of the total population of India. The urbanization in India is taking place at a very faster rate, therefore, better facilities should be provided to pedestrians from the beginning stage itself.

The performance of the entire road network totally depends on the good operating condition of junction/intersection. In India, many people are facing problems due to inappropriate planning and absence of proper pedestrian facilities on intersections. The pedestrian volume has been increased considerably in large numbers on intersections in urban areas as compared to rural areas in India. Therefore, pedestrian importance, safety and comfort shall be considered while designing the intersections. In India, the risk of collision and accidents is more as vehicles & pedestrians use the same movement space at the same time. The proper safety and remedial measures shall be taken to improve the safety, comfort and quality of roads. Researches on pedestrian-related issues have been gaining much attention from researchers in recent years, particularly pedestrian studies in terms of pedestrian level of service (PLOS). Now a day focus for evaluating pedestrian LOS has shifted from quantitative methods to qualitative methods. Crosswalks (signalized, unsignalized, and midblock) are complex locations because of the interaction of pedestrians with the vehicle. Pedestrian level of services at crosswalks is different from that on sidewalks. MOE (measure of effectiveness) is usually adopted for evaluation of pedestrian facilities, and the measure of effectiveness changes with the type of facility. Pedestrian delay and space at the corner are considered as measure of effectiveness's for intersections. The measure of effectiveness might depend on pedestrian safety,

delay, available vehicle gaps, crossing difficulty, and behavior of pedestrians while crossing as well as that of drivers at unprotected crosswalk. This study sought to identify the importance of pedestrian LOS in the context of developing countries, particularly at unprotected crosswalks. To achieve this objective, a review of the literature was carried out on the pedestrian LOS at various facilities at intersection crosswalk. The review highlighted the need for further pedestrian studies at various facilities under mixed traffic.

1.2 STUDY OBJECTIVE

- The basic aim of the study is to determine the pedestrian level of service (A-F) for Indian road condition under mixed traffic.
- To determine the pedestrian delay of a pedestrian with vehicular traffic.
- Treatment of specific Hazardous location at the intersection.
- While planning and designing the pedestrian facilities, the overall objectives would be comfort, safety and continuity.
- Reduce vehicle speeds by developing the variable speed limit.
- The main aim of the study is to reduce pedestrian conflicts with vehicular traffic to the minimum.
- According to accidental analysis Report 2017-19 at Durga Nagar shows that there is a lack of pedestrian facility and there should be a requirement of pedestrian facility.

1.3 Concept of P-LOS: -

Level of service is an overall measure of walking conditions on a route, path, or facility provided. The Highway capacity manual uses pedestrian space as primary measure of effectiveness, with mean speed and flow rate as secondary measures. There is provision of adequate space for both pedestrian moving and queuing pedestrian flow is necessary to ensure a good level of services. Alternatively, pedestrian level of services considered as pedestrian comfort, convenience, perception of safety and security. Level of services measurements consider specific constraints to pedestrian flow such as stairway and *wait time* to cross roadways. We are going to discuss LOS of walkways, LOS of queuing and LOS at signalized intersection below.

Pedestrian level of service indicates qualities of a pedestrian space and serves as a guide for development and improvement of standards for pedestrian facilities. Pedestrian spaces should be designed in consideration of human convenience and have to be qualitatively suitable to the need of human beings. The planning and design methods for the pedestrian suggested by many researchers are based primarily on *vehicular flow traffic theory*.

There are six pedestrian level of service can be expressed given below.
1. **LOS A** is a pedestrian environmental where ideal pedestrian conditions exist and the factor that negatively affect pedestrian LOS are minimal.
2. **LOS B** indicates that reasonable pedestrian conditions exist but a small number of factors impact on pedestrian safety and comfort. As LOS A is the ideal, LOS B is an acceptable standard.
3. **LOS C** indicates that basic pedestrian conditions exist but a significant number of factors impact on pedestrian safety and comfort.
4. **LOS D** indicates that poor pedestrian conditions exist and the factors that negatively affect pedestrian Level of service are wide-ranging or individually severe. Pedestrian comfort is minimal and safety concerns within the pedestrian environment and evident
5. **LOS E** indicates that the pedestrian environment is inappropriate. The situation occurs when almost all of the factors affecting pedestrian level of services are below acceptable standards.
6. **LOS F**, all walking speeds are severely restricted, and forward progress is made only by shuffling. There is frequent, unavoidable contact with another pedestrian. Cross and reverse-flow movement are virtually impossible. Flow is sporadic and unstable.
7.

1.4 Factors effecting pedestrian level of service
There are several factors affecting the level of services of pedestrian are: -

a) **Vehicle Volume:** Since, at roundabouts the movement of traffic is continuous, there is always conflict between vehicular and pedestrian movement. This conflict highly affects pedestrians' perception of safety and comfort while crossing roads at roundabouts. It has been found that PLOS decreases significantly with increase in vehicle volume.

b) **Vehicle Speed:** At unsignalized intersections, pedestrians need to find a gap in vehicular movement in order to cross a road. However, as the speed of vehicles increases at crosswalks, pedestrians are put to a greater risk of accidents. Hence, increase in vehicle speed at crosswalks has a negative effect on PLOS.

c) **Carriageway Width:** As the carriageway width increases, the pedestrians need to cover longer distance to cross the road. This also means that a pedestrian will encounter more number of vehicles vehicles and will be in the vulnerable zone for a longer duration. Hence, it negatively affects PLOS of crosswalks at unsignalised intersectiion.

d) **Pedestrian Refuge:** A pedestrian refuge positively affects PLOS and also acts as a median. It not only provides a safe haven to crossing pedestrians in the middle of the road but also facilitates a comfortable two-step crossing. The pedestrians only need to look for vehicle in one direction at a time. This greatly increases the comfort and safety level while making the crossing.

e) **Crosswalk Marking Condition:** As soon as a pedestrian step on a zebra crossing, he/she gains a right of way over vehicular

traffic. Also, a well-marked crosswalk attracts pedestrians for crossing who otherwise would cross the street at random locations endangering their life as well as of others. But the drivers need to yield to pedestrians in order to give them right of way. Sometimes, the crosswalks marking fade or are not properly visible to motorists and hence they do not yield to pedestrians. A crosswalk marking of high visibility preferably of retro-reflective type helps in increasing PLOS of crosswalks.

f) **Crosswalk Surface Condition:** A smooth, levelled and slip resistant surface is preferred by pedestrians for walking as it is more comfortable and safer than a deteriorated one. Thus, a crosswalk with good surface condition will have better LOS than a crosswalk with poor surface condition.

g) **Pedestrian delay** It is evident that the pedestrian delay is one of the factors which play a dominant role in effecting level-of-service of pedestrians on signalized intersections. Pedestrian Delay is the time up to which pedestrian waits to cross the particular road. The total delay which is experienced by pedestrian shall be classified into following patterns of delay: -
Wait time delay is basically a time gap for which pedestrian waits to cross the road through intersection.
Cross time delay basically depends on the speed of pedestrian while crossing the road. This delay poses while crossing the road.
Vehicle interaction delay is delay caused due to pedestrian interaction with vehicles.

h) **Pedestrian flow** Total number of pedestrians crosses the designated crosswalk during the analysis period.

i) **Vehicle flow rate:** Total number of vehicles crosses the designated crosswalk during the analysis period

j) **Pedestrian Platoon:** Short-term variations are present in most uncontrolled pedestrian traffic flows due to the erratic arrivals of pedestrians. On sidewalks, these random fluctuations increased due to interruption of flow and formation of queue caused by traffic signals. Transit facilities can create added streams in demand by releasing big groups of pedestrians in small time intervals, followed by those intervals where no flow occurs. Until they distribute, *pedestrians in these types of groups walk concurrently as a platoon.* Platoons also can form if flow is obstructed due to non-sufficient area, and speedy pedestrians must slow-down behind slow pedestrian.

2 RESEARCH METHODOLOGY

The methodology for calculating the pedestrian level of service majorly includes calculation of the several factors which influence the pedestrians in respect to considered safety and comfort. Determination of the pedestrian level of service at a Signalised Intersection is a complex phenomenon involving many factors. This is mainly because vehicles are running in different directions and pedestrians are to occupy the same area at the same time. Some factors such as pedestrian delay, no. of pedestrians, no. of lanes, uninterrupted traffic. The LOS methodology for a signalized intersection has a pedestrian crossing on at least one approach. The Analysis of pedestrian flow on the signalised intersection is difficult because of pedestrian passing through all the directions of the sidewalk and street and also waiting for the signal to change.

The Average delay experienced by a pedestrian is the service measure. The LOS for an un-signalized intersection can also be calculated with a pedestrian crossing in compare to a free-flow traffic stream or perspective not controlled properly by a stop sign. It is evident that the pedestrian delay is one of the factors which play a dominant role in effecting level-of-service of pedestrians on intersections. Pedestrian Delay is the time up to which pedestrian waits to cross the particular road with respect to the traffic flow. The total delay which is experienced by pedestrian shall be classified into following patterns of delay: -Wait time delay is basically a time gap for which pedestrian waits to cross the road through intersection. Cross-time delay basically depends on the speed of the pedestrian while crossing the road. This delay poses while crossing the road. Vehicle interaction delay is a delay caused due to pedestrian interaction with vehicles.
However, if zebra-striped crossing exists on the un-signalized intersection, this procedure will not be applicable due to the availability of right-of-way for the pedestrian. Therefore, pedestrian delay shall be estimated using the method for two-way stop-controlled intersections. Pedestrian Sidewalks on Urban Streets is based on pedestrian flow on uninterrupted walkway facilities of urban streets. The service measure is the average pedestrian travel speed, including stops. The average pedestrian travel speed basically depends on the distance between two points & the average time required including stops to cross that distance.

The methodology for calculating the pedestrian LOS of a pedestrian crossing of major street at intersection under the following circumstances.
- Scenario A: Unmarked crosswalk, no median refuge island;
- Scenario B: Unmarked crosswalk, median refuge island;
- Scenario C: Marked crosswalk with high-visibility treatments, median refuge island.

<u>Identify Stage Crossings:</u> When pedestrians cross in two stages, pedestrian delay should be estimated separately for each stage of the crossing by using the procedures described in Steps.
To determine pedestrian LOS, the pedestrian delay for each stage should be summed to establish the average pedestrian delay associated with the entire crossing. This service measure is used to determine pedestrian LOS for an intersection with two‐stage crossings.

<u>Determine Critical Headway</u>: The procedure for estimating the critical headway is similar to that described for automobiles. The critical headway is the time in seconds below which a pedestrian will not attempt to begin crossing the street. Pedestrians use their judgment to determine whether the available headway between conflicting vehicles is long enough for a safe crossing. If the available headway is greater than the critical headway, it is assumed that the pedestrian will cross the road, but if the available headway is less than the critical headway, it is assumed that the pedestrian will not cross the road.

For a single pedestrian, critical headway is computed with Equation: -

$tc = (L/Sp) + ts$

tc = critical headway for pedestrian (s),

Sp = average pedestrian walking speed (ft/s),

L = crosswalk length (ft),

ts = start-up & end clearance time of pedestrian (s).

Estimate Probability of a Delayed Crossing:

$P_b = 1 - e(-tc*v/n)$, $P_d = 1-[1-P_b]^L$

Pb = probability of a blocked lane,

P_d = probability of a delayed crossing,

L = number of through lanes crossed,

t_c = critical headway (s), and v = vehicular flow rate (veh. /s).

Determination of Average Delay with respect to Wait for adequate Gap:

$dg = 1/v(e(v*tc)-v*tc-1)$

Where, dg = average pedestrian gap delay (s), tc, = critical headway (s), and

v = vehicular flow rate (veh/s).

Estimation of Delay Reduction due to Yielding of Vehicles: which is determined based on the average pedestrian delay to cross the street at a pedestrian crossing. Motorist yield rate was also used as a parameter in the calculation of pedestrian delay and calculation of LOS of pedestrian crossings using HCM 2010 method. MYR is calculated as a ratio of the number of vehicles that stopped or slowed down before a pedestrian crossing and the total number of vehicles that could have stopped or slowed down in order for pedestrians to cross the road. HCM 2010 gave recommendations for MYR values based on engineers' research, so that for unmarked pedestrian crossings the value of 0 should be adopted, and for clearly marked pedestrian crossings 0,5. The study area comes under Scenario A and under Scenarios A and B, the motorist yield rates are approximately 0%. Therefore, there is no reduction in delay due to yielding vehicles, and average delay is the same. Calculate Average Delay of pedestrian and Determine level of service which is given in Indian road congress (IRC) 103-2012.

- **STEP-1**: Identify Two Stage Crossings
- **STEP-2**: Determine Critical Headway
- **STEP-3**: Estimate Probability of a Delayed Crossing
- **STEP-4**: Calculate Average Delay to Wait for Adequate Wait
- **STEP-5**: Estimate Delay Reduction Due to Yielding Vehicle
- **STEP-6**: Calculate Average Pedestrian Delay and Determine LOS
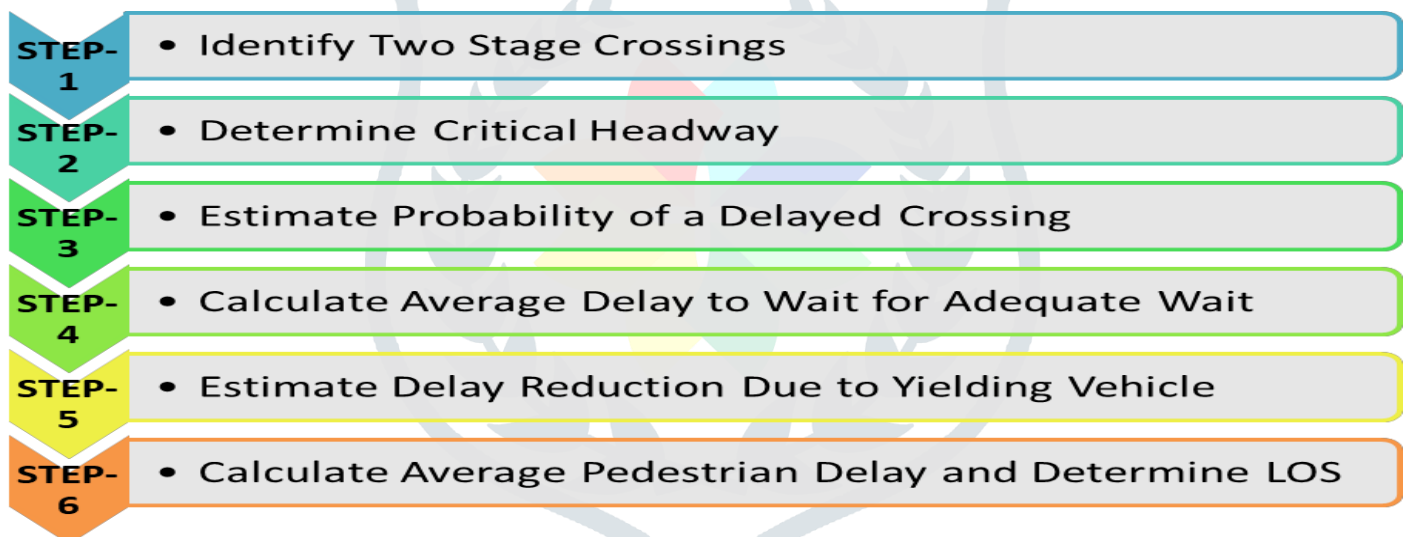
3 DATA COLLECTION

Manual method of data collection has been applied in this study. The data has been collected about the basic guidelines considered during the study. The study covers both morning and evening peak hour of traffic volume (1098 veh. /hour) and pedestrian count to analyse the existing movement pattern, pedestrian occupancy/crossing on the basis of traffic, crossing facilities and pedestrian delay at intersection. Mid-Block Crossing intersection was selected to count the amount of crossing for the period of 06 Days from 09:00 AM to 12:00 PM and 4:00 pm to 7:00 (06 hours) namely Durga Nagar Intersection on NH-146. The survey was conducted for the necessity of achieving the objective of considering exclusive pedestrian phasing. In this survey, direction wise amount of pedestrian crossing, number of pedestrians, Gender-wise occupancy, Age-wise occupancy, hourly variation of pedestrian, peak-hour pedestrian occupancy was surveyed. As the population of Vidisha city is high, therefore, large no. of pedestrian gathers in most of the intersections of Vidisha city. For the lack of timing it could not possible to count pedestrian crossing at every un-signalized intersection of Vidisha city.

The Pedestrian Volume Count was carried out for 06 hours between 09.00 am to 12.00 am and 4:00 to 7:00 in a period of 06 days from 01.04.2019 to 06.04.2019.

The following data have been collected during pedestrian volume count: -

1. Hourly Variation of Pedestrian Volume
2. Gender-wise Pedestrian Volume
3. Age-wise categorization of Pedestrian Volume
4. Peak Hour density
5. Maximum Pedestrian Crossing

3.1 During data collection

During volume count, it is observed that 2311 number of pedestrians crosses the study area on Thursday respectively. It is evident that large number of pedestrians crosses the road on Thursday compared to other days. The day-wise data is presented below: -The data was collected using manual count method for the week days in Month of April at Durga Nagar intersection in Vidisha. It includes traffic count from Bhopal to Sagar and Sagar to Bhopal. Data collection, analysis and interpretation is the most important task of the thesis. The main objective of the thesis work totally depends on the accuracy of the data analysis and interpretation. In this thesis, we have analysed the collected data and graphical representation is used. The assessment of Pedestrian Volume in the study area is essential for formulating the Level of Service for Pedestrian.

3.2 During Data collection
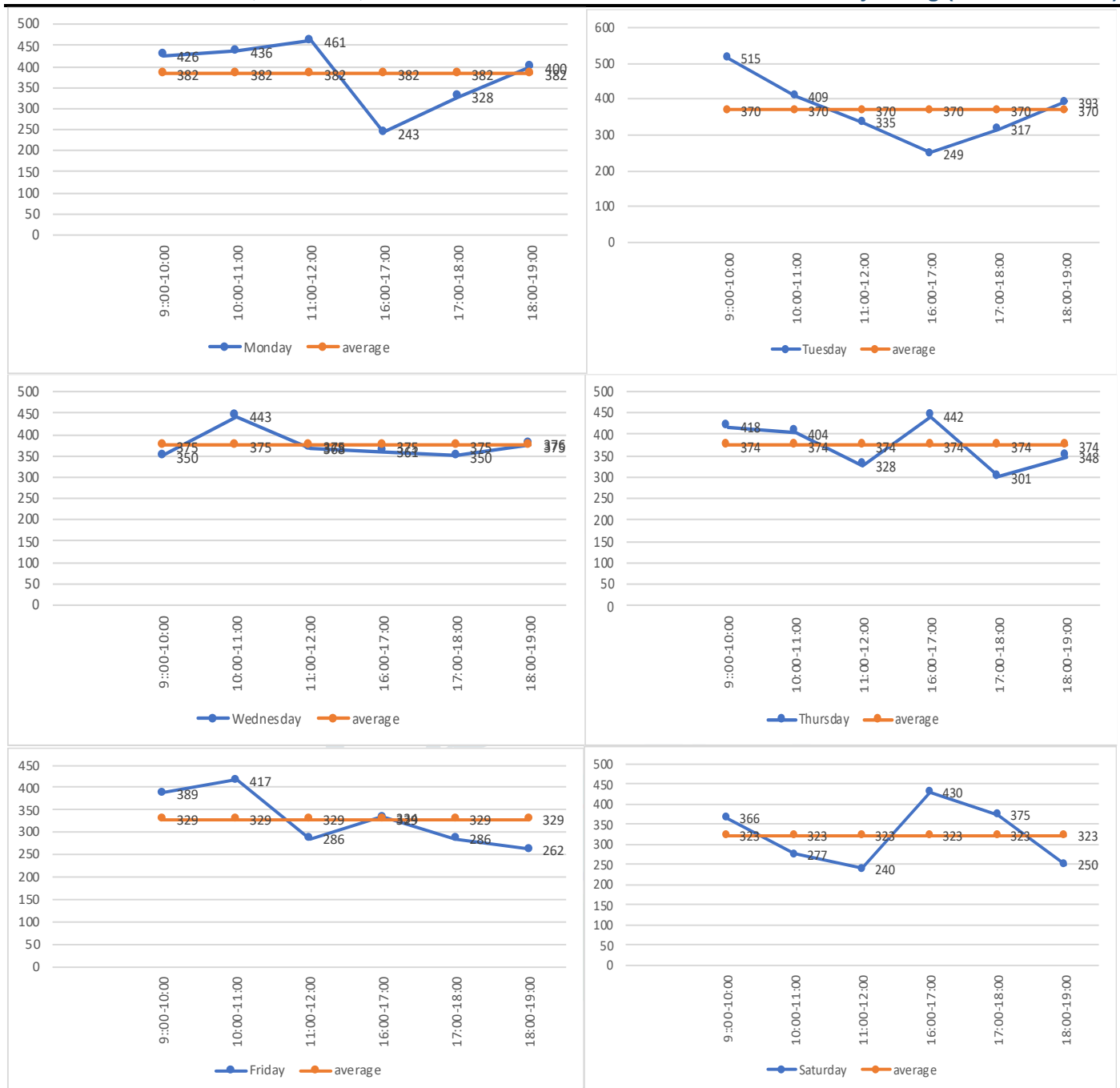
3.3 Graphs represent hourly variation

Age-wise Pedestrian Occupancy

The age of pedestrians is categorized in general into, younger, middle and old aged according to the visual appearance. The group effect of pedestrians considered, for the analysis depicts the pedestrians who cross individually one category and the pedestrians who cross with more than two pedestrians accompanying them, as other category. The interruptions for pedestrian crossing were counted when the pedestrian crossing was interfered by a vehicle on the road surface.

During the study, it is observed that total 3810 and 2472 young aged male and female pedestrians respectively, 3503 and 2069 middle aged male and female pedestrians respectively and 698 and 320 old aged male and female pedestrians respectively have crossed during the survey duration i.e. 06 Days X 06 Hours. Further, it is clearly evident that occupancy of younger aged pedestrian is on a very higher side. **49%** and 43% ,8% for middle and old age respectively.

Day wise pedestrian trend: -

This section is based on the pedestrian characteristics on the general pedestrian crossing, combined with the pedestrian characteristics of the surrounding environment and movement of Sati college students. The above analysis further indicates that the rate of pedestrian crossing occupancy is high except Friday & Saturday. As the study area is an intersection Crossing which directly connects to Railway station of Vidisha City. Hence, maximum number of pedestrian crossing occupancy is students and office worker.

TOTAL
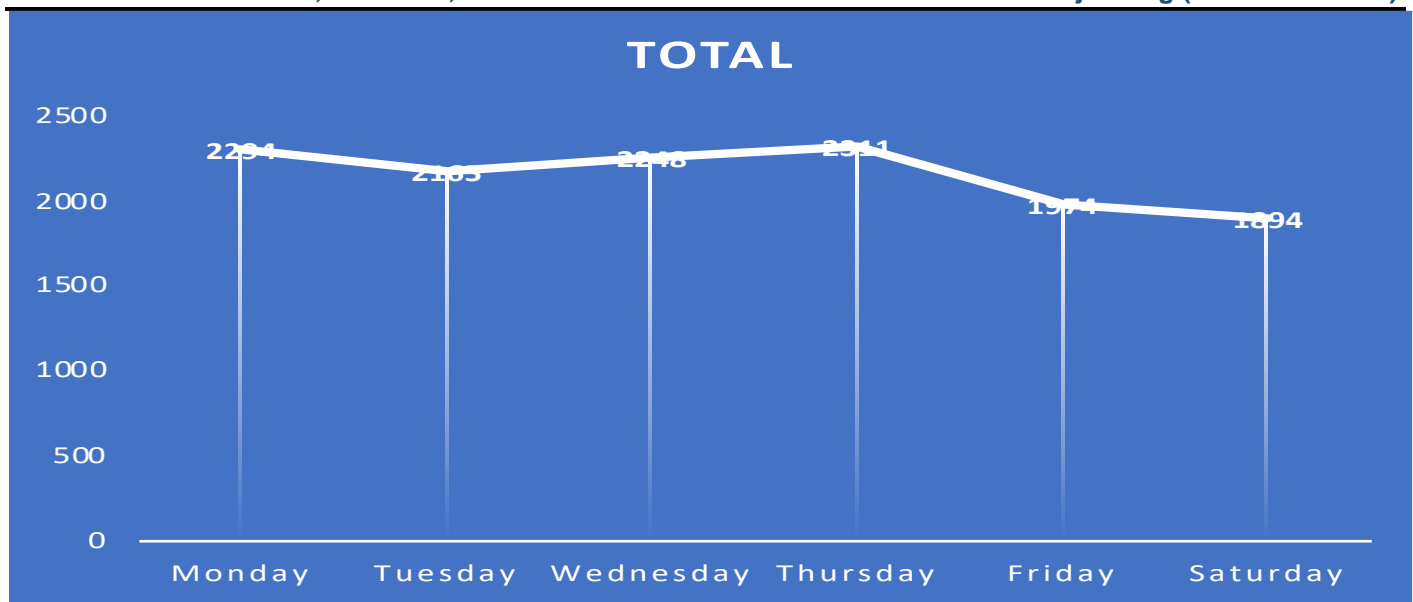
3.4 Graph represent daily variation

Observer was stand on the Road and counted manually the approaching vehicles from each direction (i.e. Bhopal to Sagar and Sagar to Bhopal) and noted the number of different class of vehicles passing the intersection in the pre-prepared table. Traffic count is taken as veh. /hour during peak hour.

Questionnaire survey was also conducted for gathering more information about that particular area and for collecting general information about perception of pedestrian. The questionnaire type survey involves interviews with the pedestrian and filled in questionnaire survey form. 33 people with different age were interviewed.

Questions which was asked by pedestrians during our survey: -

• Have you ever been hit by a vehicle while walking on the road? (yes/no) • Do you feel safe while crossing the road? (yes/no).

•   What is the perception of pedestrian for delay at Durga Nagar Square?

•   Rate the pedestrian facilities provided at Durga Nagar (0-5).

3.5 Photographs during pedestrian survey

4 STUDY AREA:

The area analysed is Durga Nagar Square. It is one of the busiest intersections of Vidisha owning to its location at on main commercial area (Durga Nagar) It handles traffic from Bhopal to Sagar, Sagar to Bhopal (NH86). Vidisha is a district place in Madhya Pradesh, India. The district is situated in the central part of the state and eastern part of the fertile Malwa region. It lies between latitude 23º20" and 24º22" North and longitude 77º15" and 78º18" East. The shape of this district is more or less elliptical and the longer axis lies from north-west to south-east with slight projections on the north, north-west, south and south-west. Its greatest length from north-west to south-east is about 133.6 km. And the greatest width from north-east to south-west is about 96 km.

The Tropic of Cancer passes through the southern stretch of the district about 2 km. south of the district headquarters. The district is bound in the north by Guna and Ashok Nagar district, in the south by Raisen, in the east by Sagar, in the north-west by Guna and in the west by Bhopal district. The total area of the district is 7,371 sq. km. which is 2.4% of the total area of the state. Its rank is 13th in terms of the area within the state.

It is located near the state capital Bhopal, 9 km from Sanchi. Vidisha is a developing city of Madhya Pradesh. Increasing number of population and vehicles growth creates high traffic flow on the roads. High volume of vehicles makes the situation of congestion on the roads. Here, the location of the study is Durga Nagar Intersection on NH-146, Vidisha District. This study has been carried out at Durga Nagar Intersection. The Pedestrian count data of both directions at NH-146 have been collected. The various patterns of pedestrian crossings on the intersection also measured. The basic aim of the study to reduce the pedestrian conflicts with the vehicular traffic to minimum and providing solution to improve the quality of the pedestrian flow. It is also taking children, elderly persons, persons with disabilities and people with heavy luggage into account.

4.1 Google map of study area

5. RESULT AND CONCLUSION

As per above methodology It is calculated that the average pedestrian delay is 49.83 Seconds per pedestrian whereas pedestrian LOS under Scenario A is LOS D in reference to the Table 1.2 of IRC: 103-2012.In view of the above data analysis, it can be saying that the study area falls under "LOS-D" in reference to the Table 1.2 of IRC: 103-2012. Calculation From this study we have found that the pedestrian facilities in the study area are very poor. The study reveals that there is absence of visible cross marking, sign boards such as speed limit, pedestrian crossing, stop, give way marking and rumble strips. The situation may be overcome by providing more pedestrian facilities on the Durga Nagar Intersection. On the basis of survey, it is clearly evident that the study area is a segment of National Highway No. 146; therefore, high volume traffic crosses the study area very frequently. and pedestrian delay is happening in the absence of Zebra Crossing and proper signage. At LOS category "D" there is 38–64 seconds waiting time, which is big delay and many pedestrians" crosses irregularly. Further, it is concluded that provision of zebra crossing at road intersection is mandatory which enable pedestrians to cross with ease as vehicles are supposed to stop before 20-50 feet (6.0 – 16.0mt) the Stop Line marking.

6. Recommendation

At-grade pedestrian crossing near intersection should be made mandatory in view of heavy volume of vehicular traffic of National Highway. Pedestrians do not have any additional protection over motor vehicles at the uncontrolled crossings. Further, the following pedestrian facilities are hereby recommended to implement in the study area. Zebra Crossing Give way and STOP marking transverse Rumble Strips, Speed Limit Sign, Refuge Island and traffic calming

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